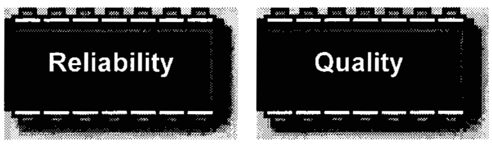
D-18791

JPL Technical Infrastructure Program
Commercial Off-The-Shelf (COTS) Parts

A report on

Plastic Parts Delamination Validation Using Failure Analysis Methods



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Office 507
Electronic Parts Engineering

Jet Propulsion Laboratory
California Institute of Technology

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Forward

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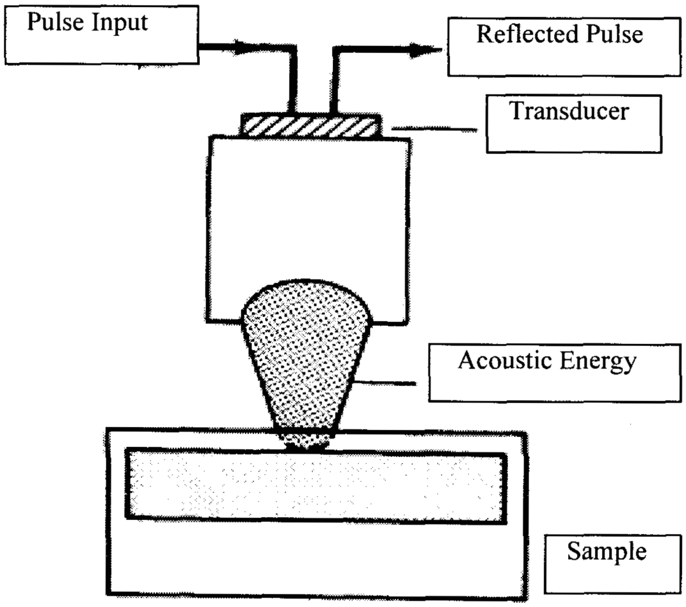
Abstract

Acoustic Micro Imaging (AMI) was successfully employed by JPL Office 507 to evaluate commercial off-the shelf (COTS) plastic encapsulated microcircuits (PEMs). A number of samples from different commercial vendors were purchased and then evaluated using C-SAM™ analysis. C-SAM™ is one of the Acoustic Micro Imaging (AMI) methods available for non-destructive detection of delamination. A number of interesting anomalies and potential reliability defects were found including minimum die attach (10%), voids at the leads within the encapsulant, thinning encapsulant, and mylar tape used in the assembly of the package. These anomalies detected by C-SAM™ imaging were analyzed using failure analysis cross sectioning to establish the validity of AMI as a tool. All anomalies and defects were verified. The success of the validation demonstrates that C-SAM™ can be used in screening parts for flight hardware. Parts that exhibit certain types of defects that could lead to long term reliability problems would be rejected based on risk criteria.

Introduction to Acoustic Micro Imaging (AMI) Technologies

C-mode Scanning Acoustic Microscope (C-SAM™) analysis utilizes reflection mode (pulse echo) technology in which a single, focused acoustic lens mechanically raster scans a tiny dot of ultrasound over the sample. As ultrasound is introduced (pulsed) into the sample, a reflection (echo) is generated at each subsequent interface and returned to the sending transducer for processing. Proper lens selection and proprietary high speed digital signal processing allow information to be gathered from multiple levels within a sample. Images can be generated from specific depths, cross sections or through the entire sample thickness and are typically produced in ten to thirty seconds. See illustration below.



Schematic of the C-Mode scanning acoustic microscope. This instrument incorporates a reflection, pulse-echo technique that employs a focused transducer lens to generate and receive the ultrasound signals beneath the surface of the sample.

Applications include nondestructive detection of delaminations between lead frame, die face, paddle, heat sink, cracks, and plastic encapsulant. The compatibility of a material is ultimately limited by ultrasound attenuation caused by scattering, absorption, or internal reflection. This technique is often used for process and quality control although it is also used for screening of devices where high reliability is desired for unique requirements such as Space applications.

JPL has employed Acoustic Microscopy Imaging (AMI) analysis to characterize plastic encapsulated microcircuits (PEMs) from different commercial IC suppliers. Reference Sonoscan Inc. report No. 3843-SSV97, dated 9/15/97. This analysis is part of an ongoing program to evaluate Commercial Off-The-Shelf (COTS) parts (including plastic packages) for reliability and their potential acceptance in Space hardware.

Previous AMI work by JPL has shown that many plastic parts do in fact exhibit delamination of different sorts. However, not all of them are necessarily serious enough to cause reliability risk. Reject criteria must be established for each case according to acceptable risk, application and environment use. The delamination validation described in this report was predicated on the possibility that AMI may not detect true delamination and that the results may be misleading. It was therefore decided that some of the samples shown to exhibit delamination would be 100% validated to a real cause or defect using conventional failure analysis methods.

Summary Table of AMI Validation:

JET PROPULSION LABORATORY
Electronic Parts Engineering Office

Validation of C-SAM Results Obtained on 3 PEMs

Precondition: 85°C/85RH for 500, 600, & 900 hrs

Found by C-SAM	Cross Section Found
Voids Near Pins (3)	Mylar Tape and Small Bubbles (3/3)
Voids at Lead Egress (1)	Thin plastic/cu oxide (1/1)
Voids at die edge (1)	No adhesion to die paddle (1/1)
Die Attach 90% Voided (1)	No Die to Frame Adhesion (1/1)

Correlation on 3 parts: 6/6

Note: Voids (delamination) are indicated as a red area with C-SAM analysis.

Background to Failure Analysis

JPL submitted **15** plastic devices to Sonoscan Inc. for nondestructive evaluation using Acoustic Micro Imaging techniques. The parts had been subjected to extended temperature/humidity tests. The purpose of the evaluation was to analyze the devices for internal defects. The samples were inspected for interfacial delamination, encapsulant voids and cracks using the C-mode Scanning Acoustic Microscope (C-SAM™). The results of their evaluation are contained in Sonoscan Inc. Report No. 3843-SSV97. Their results indicate the presence of disbonds in each of the samples. The purpose of this report is to describe the work performed in the JPL Failure Analysis Lab to verify the results obtained by Sonoscan Inc.

Their report was reviewed and it was decided to initiate the work on three samples that showed several modes of defects. The part chosen is a 32 pin dual-in-line plastic part with the following markings on the top: CSI CAT28FO20P -15 09550B. On the bottom was: TH OH951937, and in pencil was written 1, 2 and 3 as serial numbers. The parts were received in an envelope with "JOB NO. 9614624D3" printed on an identification label. It is this number plus the serial number that Sonoscan Inc. used in their report. For ease of correlation, this number was used for this analysis.

The main objective was to perform a cross section of the part to determine if the voids indicated by the C-SAM™ could be verified. A secondary objective was to determine if the extended temperature/ humidity test caused any corrosion to the die metallization. The analysis approach chosen was to dry sand through the package parallel to the die surface starting from the package top. For ease of reporting, the samples will be referred to as D3-1, D3-2 and D3-3.

Internal Failure Analysis of D3-1:

The "Top Side" C-SAM™ image indicated voids at pins 12, 21 and 28 and around the die. Sanding through showed that there are thin strips of "Mylar" tape across the package from pin 5 to pin 28 and from pin 12 to pin 21 embedded in the package and stuck to the lead frame. Sanding the plastic thin and then peeling the tape off showed air bubbles in the tape at the locations indicated by C-SAM™. See Figures 1 and 2 for Scanning Electron Microscope(SEM) views of the bubbles in the tape. The voiding around the die was not verified due to an initial lack of understanding of the CSAM™ images. Subsequent analysis of part D3-2 showed that the package material did not adhere to the exposed die heat sink material. It is assumed that D3-1 had the same situation but was missed because the assumption was that the voiding seen in the C-SAM™ was at the top of the die surface in the package material and was not found during sanding. Subsequent discussions with Sonoscan Inc. indicated that the voids would be at the die attach level and with that in mind, sample D3-2 was very carefully sanded and the void verified. See below for details of the procedure on D3-2.

The "Die Attach" C-SAM™ image indicated that there was about 90% voiding in the die attach. After sanding through the die until the silicon was very thin, the remaining thin silicon puckered indicating that it was not attached. Poking at the silicon with the point of a sharp knife broke off flakes ("slabs") of silicon verifying that the die was not adhering to the die attach material. See Figures 3 and 4 for a SEM view of the die attach area. The die attach material is a silver filled epoxy and a few small pieces (flakes) remained on the silicon. After documenting the poor die attach, further sanding was done into the heat sink and no other voids were found The remaining heat sink was lifted out of the package and no voids were found under it.

Internal Failure Analysis of D3-2:

The "Top Side" C-SAM™ image indicated slight voiding near pins 5, 12, 21 and 28 and at the end of the die near pins 10 and 23. Sanding through the package from the top in a similar fashion as D3-1, verified similar voids in the "Mylar" tape of D3-2 as was found in D3-1. See Figure 5 for SEM view of the bubble near pin 5. Further careful sanding with very fine grit paper thinned the plastic until it was noted that at the pin 10 and 23 end of the die, the remaining thin layer of plastic would move when touched with the tip of a sharp knife blade. Blowing on the thinned plastic with canned Dust-Off compressed gas with an extension nozzle lifted the thinned plastic off of the die heat sink. See Figure 6 for an optical image of the remaining die and the removed plastic package material. There was no evidence of adhesion of the plastic package material to the heat sink. The heat sink in this area is silver plated copper. The material that was blown off matches the area indicated in the C-SAM™ image.

Internal Failure Analysis of D3-3:

The "Top Side" C-SAM™ image indicated similar voiding near pins 5, 12 and 28, voiding around the die and slight voids at the egress of leads 17, 18, 19 and 20. Sanding as in D3-1 and D3-2 showed that this part also had voids under the "Mylar" tape at the areas indicated in the C-SAM™ image. See Figure 7 for SEM image of bubble near pin 21. Because the plastic was thinned at the lead egress, careful picking with a sharp knife point at the lead egress of pins 17-20 flaked small pieces of the plastic away. This indicates poor or no adhesion of the plastic to the lead material. Again verifying the results of the C-SAM™ image. The voids at the die attach level were not investigated because this part was subjected to hot fuming Nitric Acid to expose the die surface to test for corrosion of the metallization. See the discussion below for information on the corrosion tests.

Corrosion Effects Results:

As stated in the introduction, all parts had been subjected to high temperature and high humidity testing prior to the C-SAM™ imaging. All three parts were exposed to 85°C and 85% relative humidity. Part D3-1 was subjected to 500 hours, D3-2 for 600 hours and D3-3 for 900 hours at the environmental conditions. During the many stages of cross sectioning the part, metal pieces were checked for corrosion or oxidation. The results are summarized below:

D3-1 did not have any corrosion effects tested.

D3-2 did have some corrosion effects tested. The C-SAM™ image from the "Top Side" indicated a possible void at the egress of lead 4 from the package. During the sanding procedure when the plastic was thin above the leads, the sharp tip of a knife blade was pushed against the thin plastic on lead 4 and the remaining plastic broke free. This indicates that there was no bonding of the plastic to the lead frame. The lead frame material is copper. The visual appearance of the lead frame surface was not bright shinny copper, but had a dull cast to it. The lead surface was analyzed with the Energy Dispersive Spectrometer (EDS) attachment to the SEM. The results indicated that the surface had copper and oxygen. Lead 1 was also analyzed in a similar manner and it too had copper and oxygen. This lead did not indicate any voiding in the C-SAM™ image. As a final check, the interior portion of lead 12 was exposed and it was bright shinny copper color and the analysis showed only copper and no oxygen.

D3-3 was used to check for corrosion on the die surface. The die surface was exposed using a special piece of equipment that subjects the part to hot Fuming Nitric acid through a mask. The mask tends to limit the area that is treated. However, there is some undercutting. The acid attacks the plastic and the copper leads, but not the silicon die, aluminum metallization and the gold leads. Since the die is passivated, the aluminum metallization that is exposed is only around the die bond pads. A careful examination with the SEM did not indicate anything that could be related to corrosion. See Figure 8 for SEM image of typical die bond pad following passivation removal.

Conclusions:

The objective of this undertaking was to validate if any or all results obtained by AMI on plastic parts would correlate to real physical causes. If correlation was proven, then AMI would serve as a valuable tool in the evaluation and possible screening of plastic parts for undetected defects leading to reliability failures under field conditions. Some of the samples evaluated by JPL were selected to undergo a complete failure analysis for each AMI problem found. A total of six AMI problems found were analyzed using cross sectioning techniques. Definitive results were found on six problems areas. The failure analysis results has therefore established credibility for using AMI and C-SAM™ as a screening methodology. AMI will have tremendous value for JPL in reliability evaluation and even qualification of new parts and materials. More work is necessary to establish what criteria is allowable for some of the more common AMI problems and defects identified.

For further information contact Ken Evans x4-4834 or Mike Sandor x4-0681.

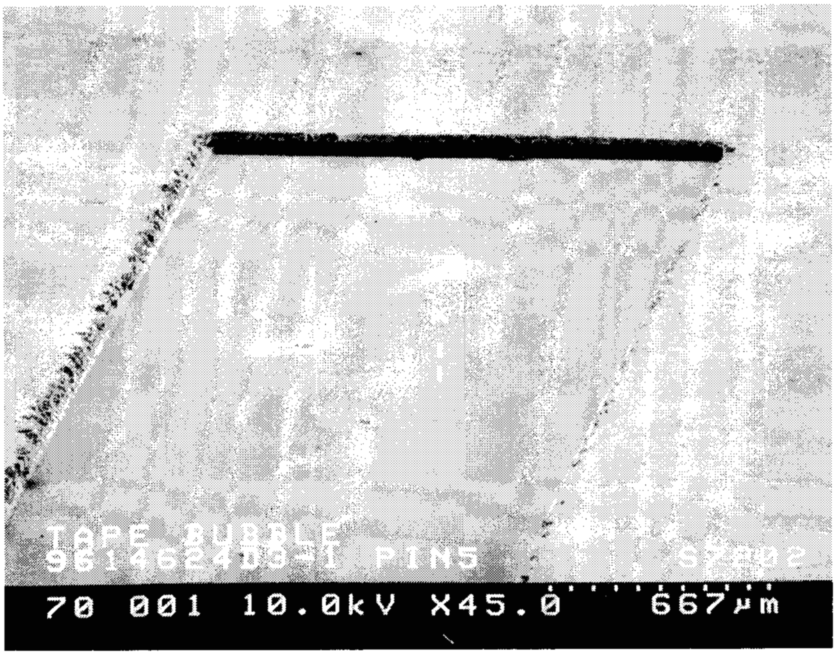


Figure 1. The arrow indicates the bubble in the "Mylar" tape of sample D3-1 near pin 5 in this SEM image.

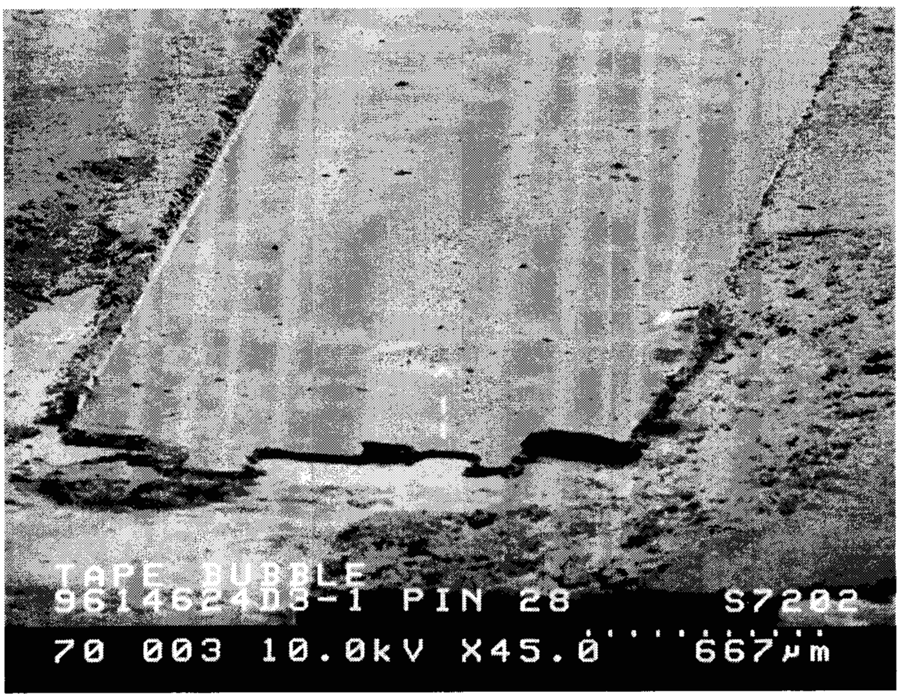


Figure 2. The arrow points to another tape bubble on D3-1 near pin 28.

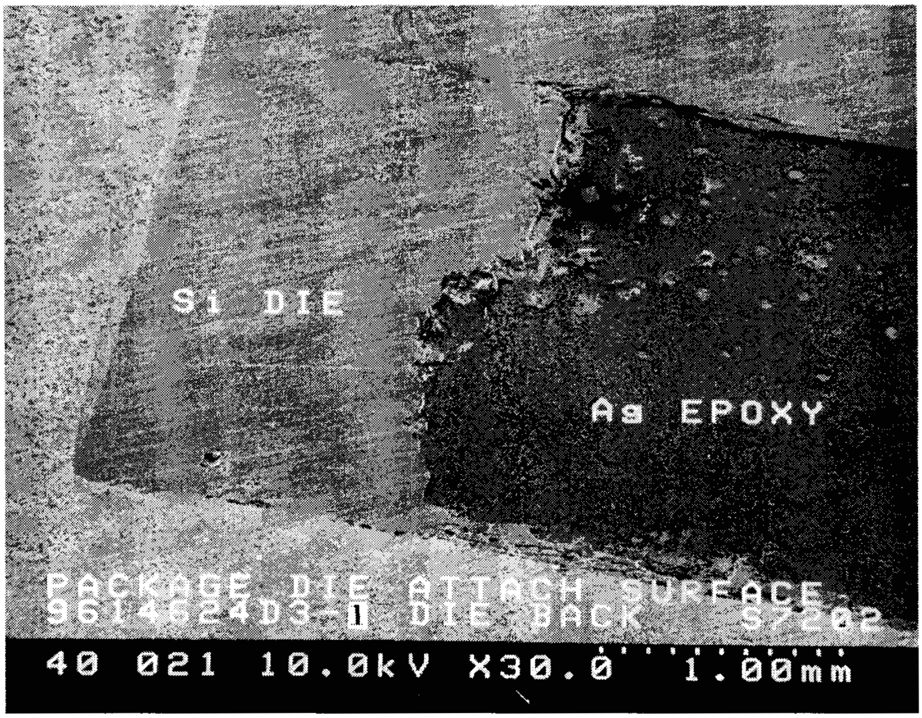


Figure 3. This SEM view is of sample D3-1 and shows the sanded package with a thin layer of the silicon die and the exposed die attach silver filled epoxy.

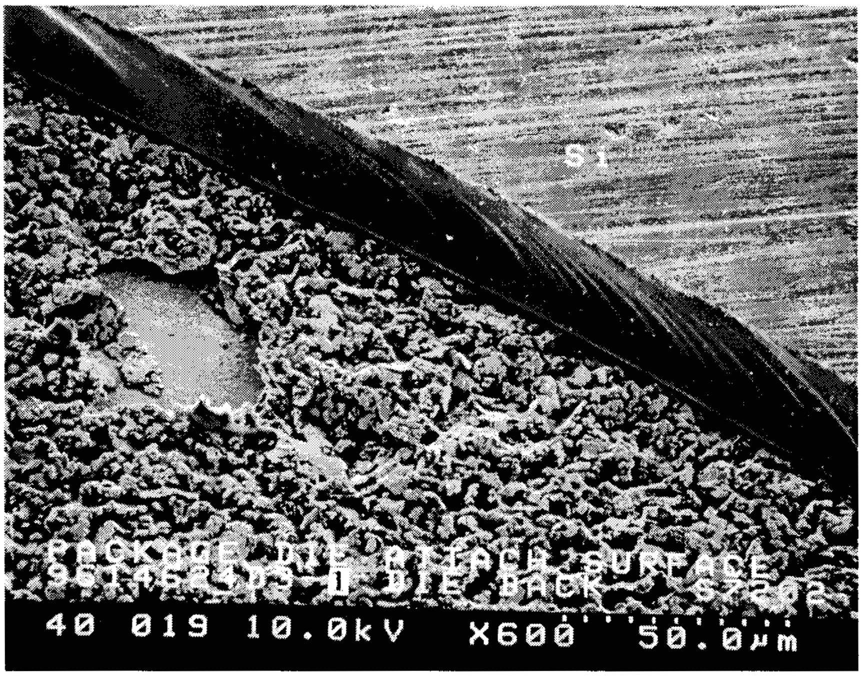


Figure 4. A close-up view of the remaining silicon wafer and die attach material of D3-1. Note that the die attach material surface is very much intact due to non-adhesion to the silicon die. Also note that die attach material is missing from the heat sink surface.

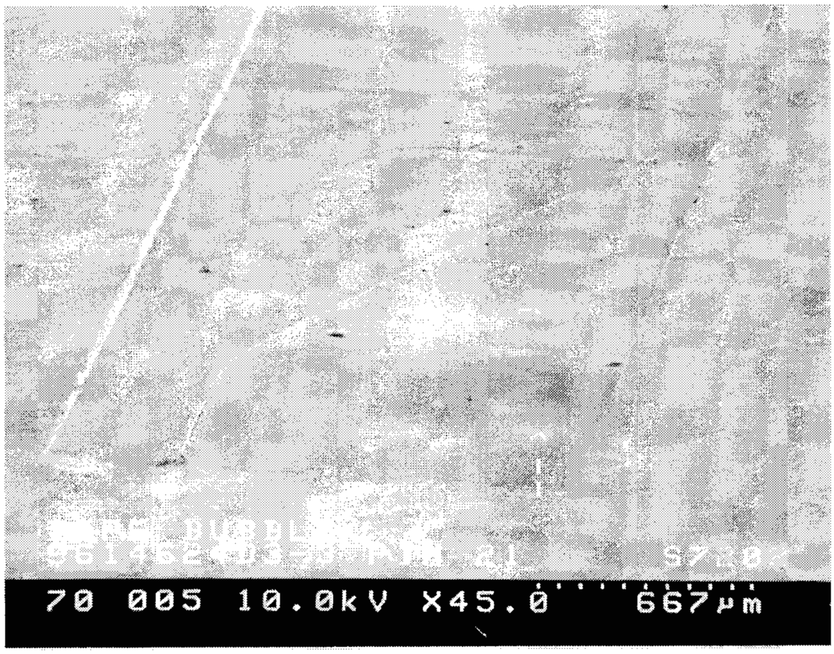


Figure 7. This SEM view is of the "Mylar" tape bubble of Sample D3-3 near pin 21.

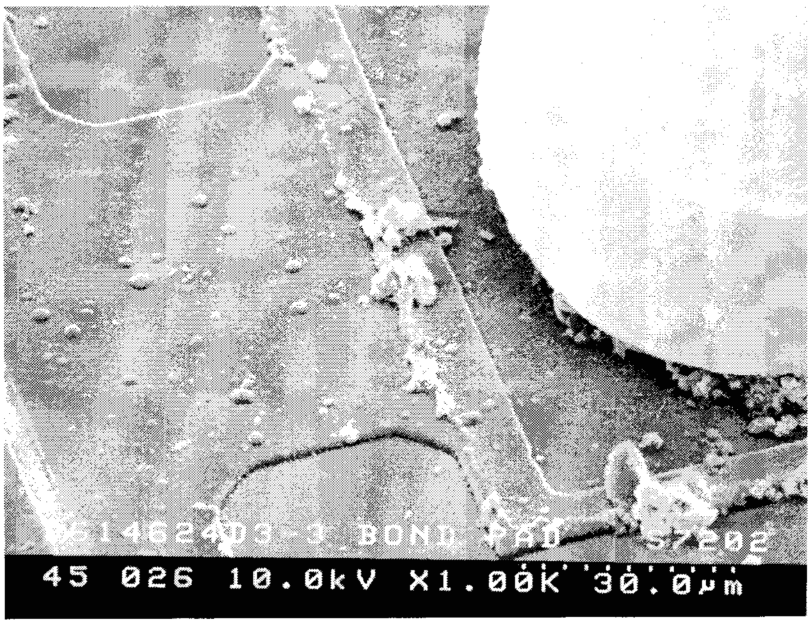


Figure 8. A SEM view at 1000x of a typical die bonding area of Sample D3-3 after passivation removal. The small particles are debris left over from sample preparation.

Figure 5. SEM view of the bubble in the "Mylar" tape of D3-2 near pin 5.

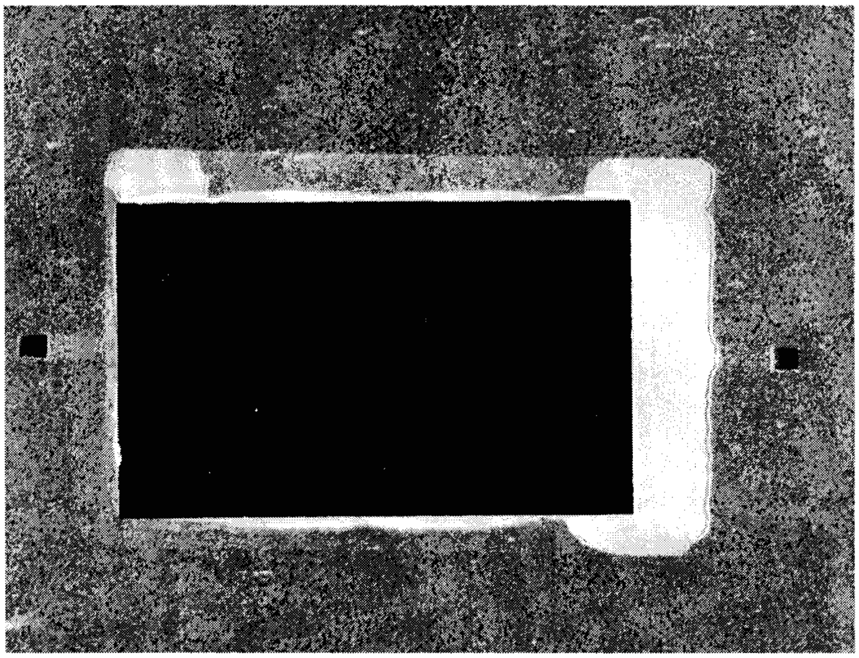


Figure 6. Optical view of D3-2 after sanding until the die is very thin. Compressed gas blew away the thinned plastic package material. The large dark rectangle is the remaining die, the gray area is the package material and the light area is the exposed heat sink.